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6G

FLAGSHIP

UNIVERSITY
OF OULU

The Role of Spectrum Towards 100GHz and Beyond in 6G

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6G Flagship - Key Figures and Research Areas

Key Figures for First Two Years

Staff

305
experts in 2020



58
Nationalities

Publications (May 2018 – September 2020)

1 151
Peer-reviewed publications
/ Journal and conference articles



65% International joint publications
75% Joint publications with collaborators
11% Joint publications with companies

Collaboration (May 2018 – September 2020)

259
Research projects with
external funding



136 New company
collaborators
85 Companies investing in
research portfolio

Doctoral Degrees (May 2018 – September 2020)

46
Doctoral degrees



178 861
Doctoral thesis downloads
Number of downloads in University of Oulu
repository <http://jultika.oulu.fi/>

1.

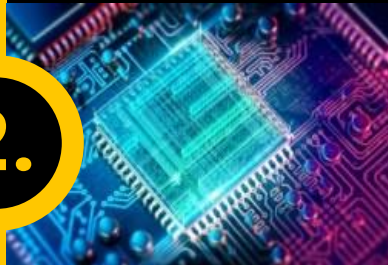


Wireless Connectivity

Ultra-reliable low-latency communications vs. 1 Tbps

Enabling **Unmanned Processes**

2.



Devices & Circuits

THz communications materials & circuits

Enabling **Unlimited Connectivity**

3.



Distributed Computing

Mobile edge intelligence

Enabling **Time Critical & Trusted Apps**

4.



Services & Applications

Multidisciplinary research across verticals

Enabling **Disruptive Value Networks**



Value Chains Reformed Every 20-Years

Wireless connectivity is driving major societal changes:



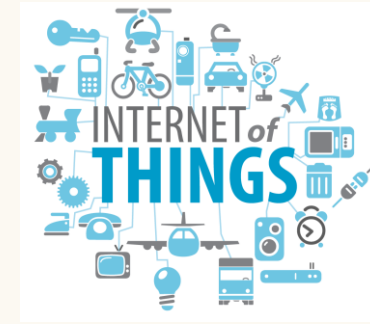
1G - 2G

1980s – 2000s
Millions of voice users



3G - 4G

**– 2020s Billions of Mobile
Broadband users**



5G and beyond

**– 2040s Trillions of
connected objects & intelligence**

Applications range explodes and **new value chains** emerge:



Logistics



Retail



Agriculture



Industry 4.0



Health



Energy



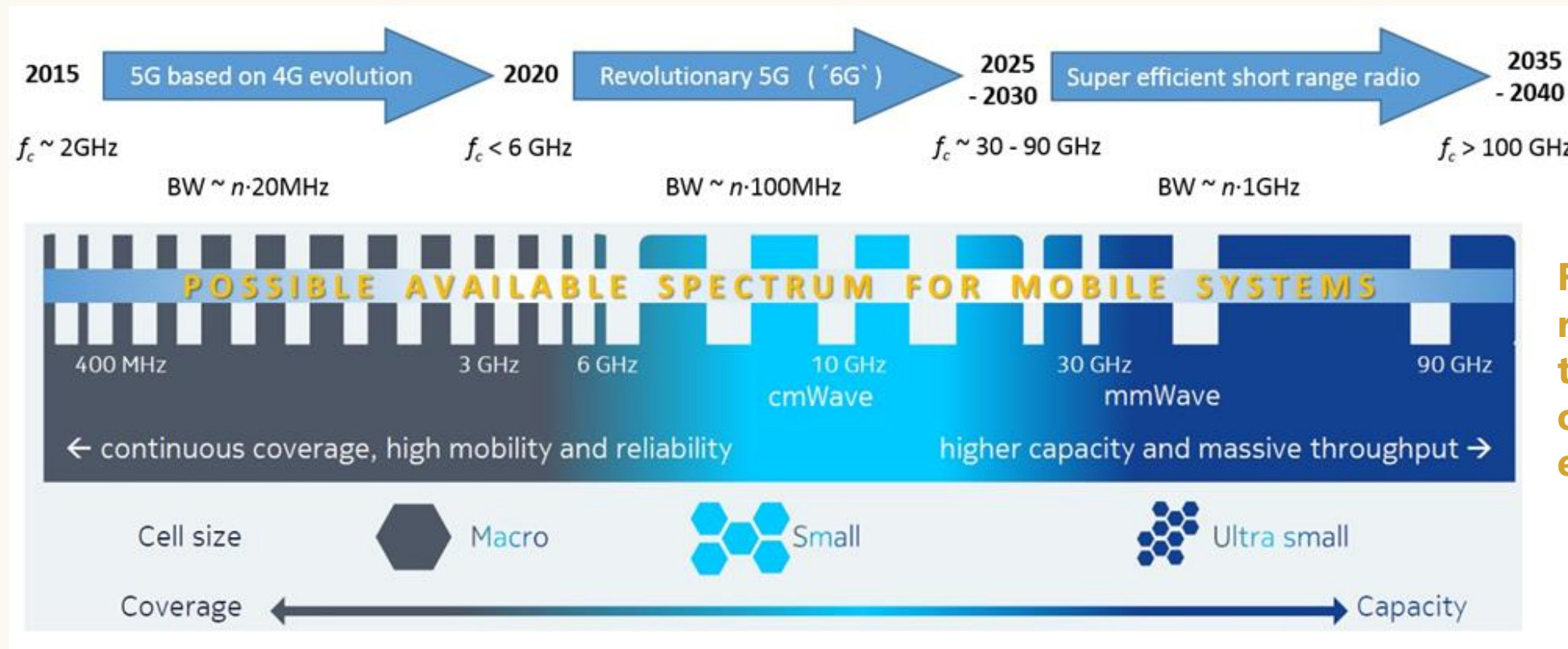
Automotive

**5G will be succesfull once the value chains related to key verticals are
thoroughly understood driving evolution towards new business ecosystems.**



Regulation Policies Enabling Future Innovations

Example: Frequency spectrum regulation for mobile wireless systems (our guess made in 2015)



Flexible and innovative regulation policy is key to enable development of future verticals and ecosystems.

Critical Drivers Towards 6G



Society

- **Digital inclusion via global coverage**

- Connectivity is key to satisfy UN SDGs and needs of digital societies; current terrestrial technologies with evolutionary features need to be complemented by specific remote areas solutions including satellite.

Business

- **New ecosystems and disruptive business models**

- Digital societies and emergence of new verticals create new ecosystems and disrupts current business models requiring field specific regulation changes; ownership of customers and networks changes.

Security

- **Data privacy and security**

- Expansion of verticals with new stake holders and emergence of large number of new players providing different network elements, critical applications and operating different parts of networks sets new privacy & security requirements.

Radio tech

- **Super efficient connectivity at high spectrum bands**

- Extreme speeds, reliability, low latency and localization/sensing accuracy can be achieved only locally in rather short-range networks utilizing existing frequency bands and the new ones above 100GHz.

AI

- **Smart AI enabled networks and applications**

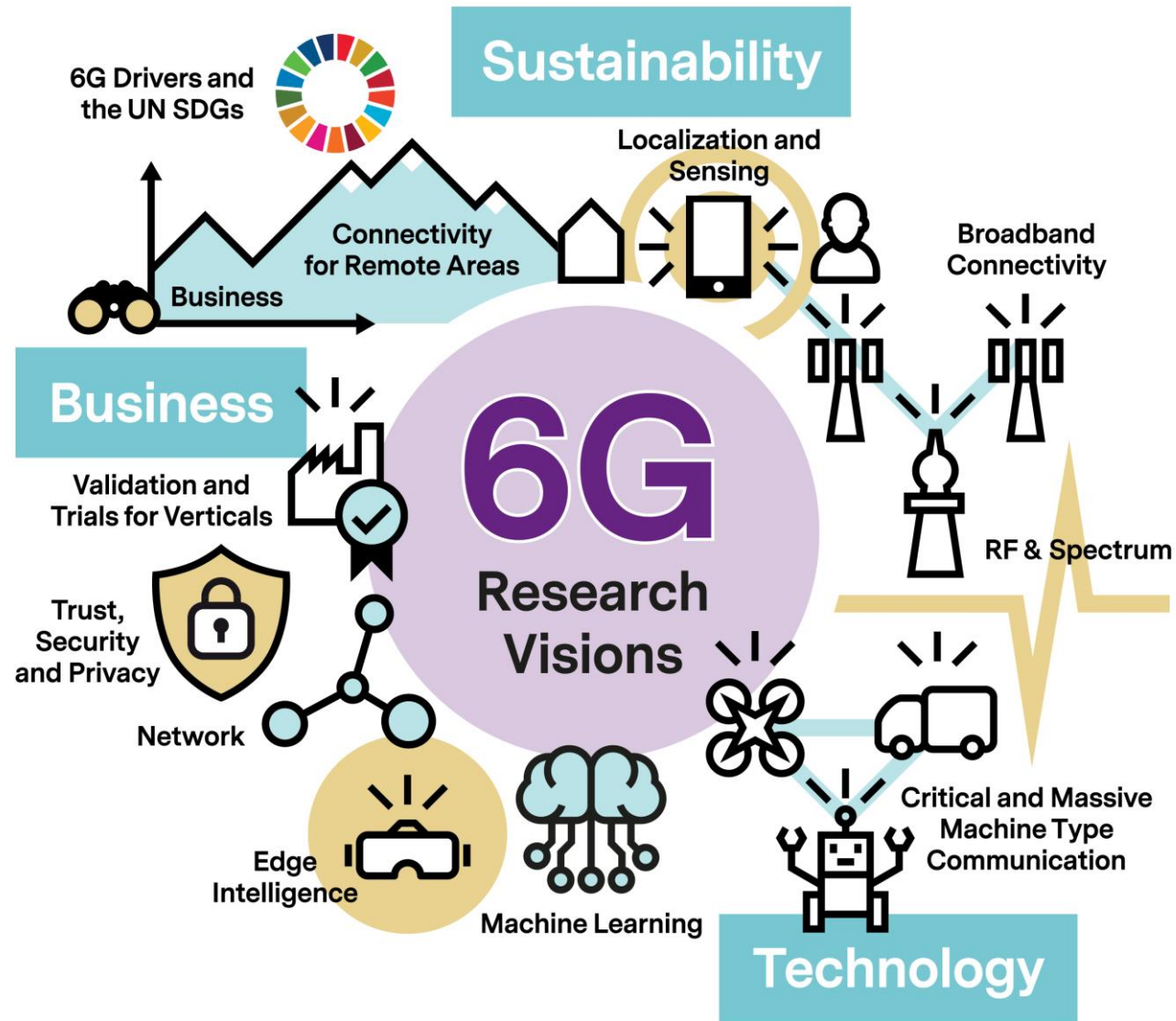
- Networks and applications become intelligent, self-learning and context dependent; edge intelligence is the key technical enabler and challenges/complements centralized cloud solutions.

Standards

- **Global collaboration and standards**

- 6G coalitions forming in a new geopolitical landscape; a new standard is introduced after every 10-years – business reshaped in 20-year cycles; spectrum regulation principles changing ~25++ year cycles.

6G Playground



All these aspects are considered in 12 White Papers produced by 250 leading experts from 100 organizations:
<https://www.6gchannel.com/6g-white-papers/>

WHITE PAPER ON RF ENABLING 6G – OPPORTUNITIES AND CHALLENGES FROM TECHNOLOGY TO SPECTRUM

6G Research Visions, No. 13
2021



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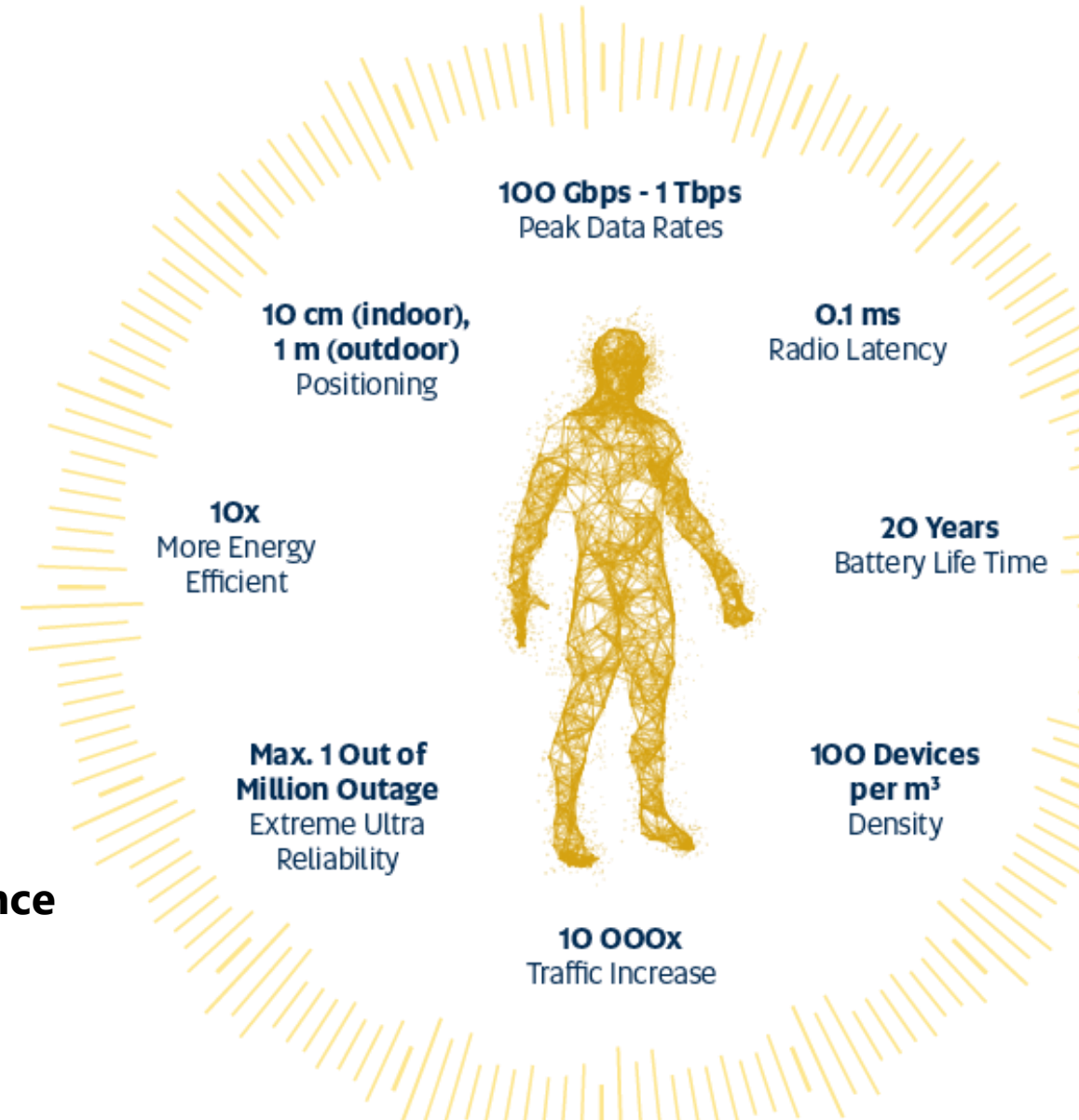
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Published in the coming weeks

6G Ofcourse Also for Super Efficiency



- **Tbps connectivity**
- **Absolute communication reliability**
- **100% security**
- **Zero communication latency**
- **Cm-level positioning accuracy and 3D radio imaging**
- **Global coverage including remote areas**
- **Fully automated networks optimization and deployment**
- **Smart context dependent content delivery**
- **Utilization of all human senses for immersive user experience**

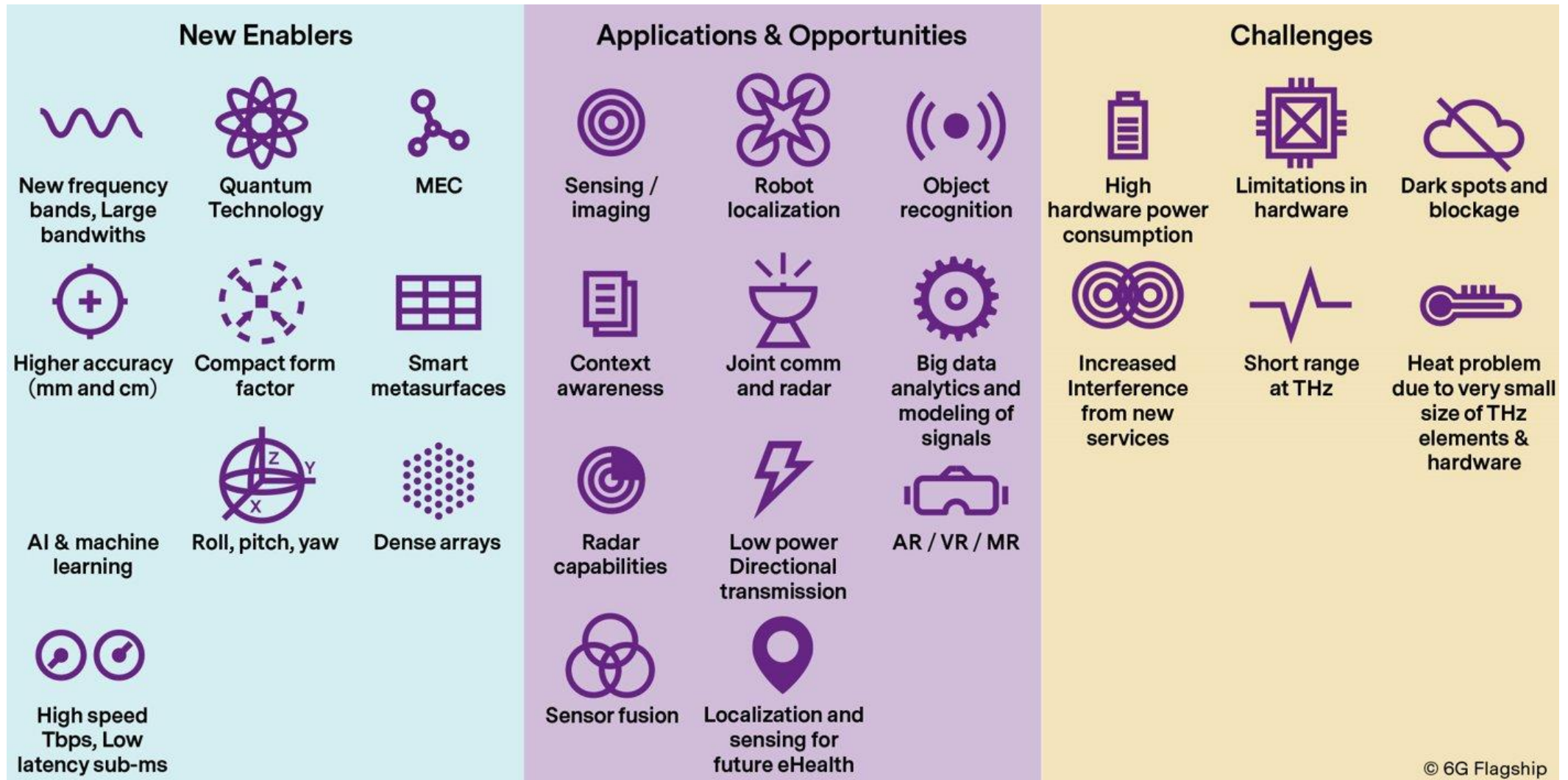


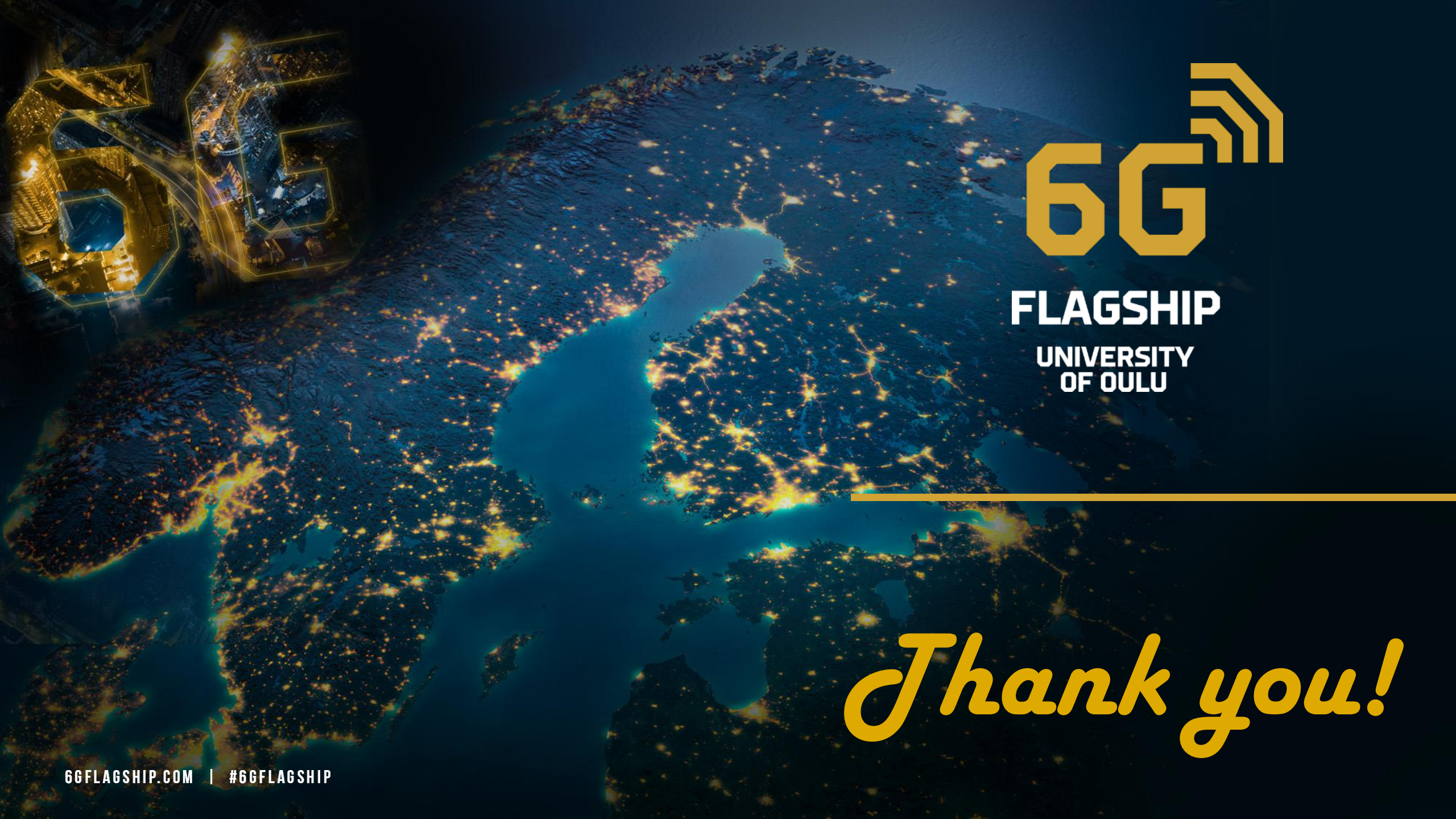
Broadband Connectivity Challenges



Summary of key open problems		
Challenges	Potential 6G solutions	Open research questions
Stable service quality in coverage area	User-centric cell-free massive MIMO	Scalable synchronization, control, and resource allocation
Coverage improvements	Integration of a spaceborne layer, ultra-massive MIMO from tall towers, intelligent reflecting surfaces	Joint control of space and ground-based APs, real-time control of IRS
Extremely wide bandwidths	Sub-THz, VLC	Hardware development and mitigation of impairments
Reduced latency	Faster forward error correcting schemes, wider bandwidths	Efficient encoding and decoding algorithms
Efficient spectrum utilization	Ultra-massive MIMO, waveform adaptation, interference cancellation	Holographic radio, use-case-based waveforms, full-duplex, rate-splitting
Efficient backhaul infrastructure	Integrated access and backhauling	Dynamic resource allocation framework using space and frequency domains
Smart radio environment	Intelligent reflecting surfaces	Channel estimation, hardware development, remote control
Energy efficiency	Cell-free massive MIMO, suitable modulation techniques	Novel modulation methods with limited hardware complexity
Modelling or algorithmic deficiencies in complex and dynamic scenarios	ML-/AI-based model-free, data-driven learning and optimization techniques	End-to-end learning/joint optimization, unsupervised learning for radio resource management

Opportunities of Localization and Sensing





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Thank you!